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OF

SUGAR BEET GROWTH AND SELECTION

BY

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ABSTRACT

The rate of growth and development of two sugar beet varieties, one characterized by high-root-yield and low-sucrose-content and the other by low-root-yield and high-sucrose-content, was studied under field conditions for two years. Yields of dry matter increased continuously from mid-July until mid-October for a high-root-yield variety. A high-sucrose-content variety declined in rate of root-dry-matter accumulation after the advent of cold weather in early September. Both varieties increased in percentage sucrose on an apparently straight-line basis from mid-July until mid-October. The results for fresh root yield, sucrose yield, percentage dry matter, percentage purity and percentage sucrose on dry weight are also given.

A high-root-yield variety gave a greater root yield response to high levels of fertilizer than did a high-sucrose-content variety. A high fertilizer treatment resulted in significant reductions in percentage sucrose, percentage dry matter and percentage purity for both varieties.

An experiment evaluating the progeny of plants selected for percentage dry matter of the petiole showed that significant changes had been obtained in percentage dry matter of the petiole, percentage sucrose, percentage dry matter of the roots, root weight and sucrose yield.

A further experiment demonstrated that percentage dry matter of the leaves and petioles of young sugar beet plants may be used to predict the potential root yield and percentage sucrose of sugar beet varieties and strains.

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INTRODUCTION

Recognition of the root of the biennial sugar beet plant (Beta vulgaris L.) as an economic source of sucrose has stimulated its use in an ever increasing number of genetical, physiological and biochemical studies. Such studies (10,11,14,16, 39,40) have demonstrated the importance of detailed investigation under controlled conditions of specific reactions responsible for sugar beet growth and sucrose synthesis and storage. A constant awareness, is necessary, of the complex interlocking of many unit processes under nonconstant environmental conditions to produce the plant, as we know it, with a relatively high photosynthetic efficiency.

Continued success by plant breeders (7, 17) in improving sugar beet varieties has unequivocally shown that the root weight and percentage sucrose can be increased by changing the genetic constitution through selection, but that there is generally a strong, genetically-controlled negative correlation between root weight and percentage sucrose. Striking environmentally induced negative correlations between root yield and percentage sucrose have been readily demonstrated by studies of sugar beet growth (17, 20, 23, 25). Extensive research has also shown that higher yields of sucrose per acre usually are a result of increses in root weight alone or in conjunction with an increase in percentage sucrose, and rarely due mainly to an increase in the latter.

One purpose of these experiments was to evaluate the effect of some environmental factors on the growth and development of two genetically different sugar beet varieties, and thus provide information that would permit an indirect assessment of some basic phenomena that

may differentiate a high-root-weight low-sucrose-content variety from a low-root-weight high-sucrose-content variety. In assessing these basic phenomena liberal reference is made to pertinent results obtained from investigations with organisms which possess more readily defined biochemical-genetical systems. The other purpose was to assess the practical value of measuring percentage dry matter of the petiole for the effective selection of individual plants for root weight and percentage sucrose, and also for the prediction of potential root yield and percentage sucrose of varieties and strains.

All experiments, unless otherwise stated, were conducted on the Research Farm of the Canadian Sugar Factories, Taber, Alberta.

REVIEW OF LITERATURE

Experiments conducted in Colorado (12) demonstrated a significant variety by date-of-harvest interaction for root yield and percentage sucrose and indicated the importance of considering the date of harvest when evaluating varieties. Conversely, in California (25) it was found that a high-root-yield low-sucrose-content variety reacted similarly toward increased nitrogen nutrition and dates of harvest, except that a high-root-yield variety continued to respond relatively more, than a high-sucrose-content variety, to the higher levels of nitrogen nutrition. The significant variety by date-of-harvest interaction obtained was due to the high-root-yield variety gaining relatively more in root yield with increasing length of the growing period. Thus the date-of-harvest was not very critical when evaluating varieties.

After extensive experimentation Ulrich (54) concluded that "sugaring-up" of sugar beet plants depends on environmental conditions. By lowering the day and night temperatures, with the day length remaining constant, the percentage sucrose was increased from between 8 to 10 per cent up to 12 per cent. Previously (53) he had concluded that during the early period of growth of the sugar beet plant, the sucrose concentration of the beet root increased slowly and then gradually reached a maximum value of 8 to 10 per cent at the time of maximum development. Thereafter the sucrose concentration of the storage root remained relatively constant over a wide range of light intensities and day length. Went (61) reported that the percentage sucrose of beets was inversely proportional to the temperature. Nyctotemperature was slightly more effective than phototemperature. The highest percentage sucrose was reached at 4°C, whereas at 30°C the sucrose percentage was lowest. In a controlled climate

experiment Ulrich (55) showed that climate in a 75 day period immediately preceding harvest had a highly significant effect on the percentage sucrose whereas the climate 56 days immediately after planting had no stat istically significant effect. Later (56) he found no significant correlation between percentage sucrose and the minimum night temperatures above 0°C summed for four weeks prior to harvest using a standard variety grown in nutrient culture in seventeen sugar beet growing areas in the United States.

Numerous experiments have demonstrated the effects of environmental factors on plant growth. Pierce (43) found that practically all increases in soil temperature from week to week were accompanied by corresponding increases in growth rate, and vice versa. Weekly growth of sugar beets was greatest when average weekly air temperature was about 24°C. Tobacco and gourd plants (36), growing in moist soil under conditions favouring a low rate of transpiration, wilted when the soil was cooled to 3 to 5°C, but recovered when it was warmed to 12 to 18°C. Furthermore, when respiration of actively accumulating tissues was decreased by chemical inhibitors, low temperatures or inadequate oxygen supply the accumulation of solutes was invariably decreased or stopped (36). The reduction in rate of water absorption as a result of lowering the root temperature varied with the plant species (8), but generally and abrupt decrease in root temperature resulted in an abrupt decrease in water absorption. The level of nitrogen nutrition (23) and irrigation practices (20) influenced both the percentage sucrose and the percentage dry matter of the sugar-beet root, whereas calculations made from other data (47) indicated that various fertilizer treatments resulted in sucrose percentages ranging from 14.2 per cent

to 16.7 per cent, while the percentage dry matter of the roots remained constant. Other experiments have shown that chemical treatments increase the sugar content and the rate of water loss from sugar-beet seedlings (37).

At temperatures below 24°C beets showed a close relationship between temperautre and respiration rate, whereas at temperatures above 24°C the rates of respiration increased more rapidly in proportion to the temperature rise than at the lower temperature (5). Went (60) reported that plants with a high respiration rate were, in general, those which grew most rapidly. There was a slight positive correlation between the respiration rate of the leaf discs and subsequent increases in weight. Nelson (42) found no apparent relationship of respiration rates with yield or sucrose percentage. Stout (50), however, showed that large beets respired more slowly than an equal weight of small beets. The rate appeared to be correlated with the surface area per unit of weight. In this study respiration rate was positively correlated, although not significantly, with the percentage sucrose. Selection for low respiration rates has been effective (42, 51). A later study (52) indicated that an increase in the sucrose concentration of the medium in which tests were made caused a reduction in respiratory rate. Diurnal fluctuations, in the respiration rates of the intact root, have been demonstrated for several plant species (30). Went (61) found that at light intensities of 1270 foot candles the photosynthetic process of young sugar beets was completely saturated and that another process was limiting the rate of dry matter production. Rabinowitch (44) has discussed, not only within but also between species, differences in rates of photosynthesis and adaptation. Some plants (44) have been shown to recover their

photosynthetic capacity more quickly after being subjected to adverse temperatures.

Beet root tissue (52) has shown stimulated respiration rates when the medium contained NaCl whereas maize roots (21) did not increase in respiration rate when the medium contained NaCl. Although respiration and photosynthesis rates are reduced by lower temperatures, translocation of sucrose from the leaf of the sugar beet is equal to or greater at 3°C than at 21°C (31).

Savitsky (48) stated that selections, of individual sugar-beet plants, for root weight were more efficient when made in summer than when they were made in the fall.

MATERIALS AND METHODS

GROWTH STUDY

Field experiments were conducted during the growing seasons of 1961 and 1962, to study the rate of growth and developement of two diploid sugar beet varieties. CS7, a high-root-yield variety selected, from a high tonnage variety obtained from England, for commercial production in Western Canada and A90, a variety obtained from Poland and characterized by very low root yield and a very high sucrose percentage were used. In both years a split-plot design with eight replications was used. The main plots (eight harvest dates) were arranged as a latin square. Superimposed on each main plot were two 35 feet long one row sub-plots (varieties). The rows were spaced twenty-two inches apart. After emergence the plants were thinned to ten to twelve inches within the row.

The experiments were planted on May 18 and April 26 in 1961 and 1962 respectively. The harvest dates for each of the two years were as given below.

Harvest date	1961		1962	
I	July	17	July	17
II	August	1	July	31
III	August	15	August	14
IV	August	29	August	28
V	September	12	September	11
VI	September	26	September	24
VII	October	10	October	9
VIII	October	24	October	19

On each harvest date the roots from 25 feet of row per plot were dug, immediately washed, weighed and processed through a multisaw beet rasp to provide a uniform sample of finely divided pulp. Percentage sucrose and percentage purity were determined by a hot water extraction method described by Browne and Zerban (9). The percentage purity = (sucrose as measured by direct polarization divided by total dissolved solids as measured by a refractometer) multiplied by 100. Dry matter was determined by drying the samples in a forced draft oven for 48 hours at 90°C. Sucrose per acre, dry matter per acre and percentage sucrose on dry matter basis were obtained by making the appropriate calculations. The analysis of variance was performed as outlined by Goulden (19). The two varieties were compared separately for each character on each harvest date in each year. The variety by date statistical analysis was performed separately for each character and each variety. Air temperature data were obtained from the Department of Transport Climatological Station, Taber, Alberta and is given in Fig. 1.

VARIETY BY FERTILIZER

In 1962 an additional experiment was conducted to determine whether the above two varieties would react differently, with regard to the above described characteristics, to very high levels of soil nitrogen and phosphorous. A split-plot design with ten replications was used. Two fertilizer treatments constituted the main plots. The sub-plots consisted of the two varieties CS7 and A90 and were of the size described for the growth study. The experiment was planted on April 26, 1962. After emergence the seedling stand was thinned to 10 to 12 inches between plants within the row. The normal fertilizer

treatment, applied to all plots, was equivalent to four grams uniformly incorporated into the seed bed prior to planting. On August 10 each plant on the high fertilizer treatment received 15 grams of a 1: 1 mixture of the two granular commercial fertilizers: ammonium phosphate (11-48-0) and ammonium nitrate (33.5-0-0). The fertilizer was injected five inches deep and four inches to the side of the tap root. The experiment was harvested on October 19, 1962 and the roots were processed as described for the growth study.

INDIVIDUAL PLANT SELECTION

The details of the methods of selecting individual plants, which deviate from the mean of each population in excess of that expected by chance has been described earlier (7). Divergent selections were made from each of three populations, CS7, A90-54 and 5957 for percentage dry matter of the petiole as shown in Table 1. Seed was produced from each of the selections by permitting the plants within each group to interpollinate in isolation. Nine, eleven, and twelve roots were selected for high percentage dry matter of the petiole from CS7, A90-54 and 5957 respectively. The seed produced in 1961 from the selected roots was numbered 6139, 6140 and 6141 respectively. Six, three and four roots were selected for low percentage dry matter of the petiole from CS7, A90-54 and 5957 respectively and the seed produced in 1961 from these selected roots was numbered 6142, 6143 and 6144 respectively. In 1962 seed of the above selections and their parents was planted in a field experiment to evaluate the effectiveness of the selection method. Strain 6143 produced insufficient seed for testing. The field experiment

consisted of eight replications. The one row plots were 60 feet long. The experiment was planted on April 26, 1962 and fifty feet of row was harvested on September 25, 1962 for analysis.

TABLE I

PLANTS SELECTED FROM OPEN-POLLINATED POPULATIONS FOR PERCENTAGE DRY MATTER OF THE PETIOLE

Accession number	Description	No. of roots	Petiole, % dry matter	Root, wt. oz.	Root, % sucrose
CS7	Standard tonnage	100	11.42	27.0	17.5
6139	High % dry matter ex CS7	9	14.21	26.7	18.8
6142	Low % dry matter ex CS7	6	9.07	22.0	16.4
A90-54	High-sucrose-content Udycz A	100	13.09	19.7	19.9
6140	High % dry matter ex A90-54	11	15.75	20.0	20.5
6143	Low % dry matter ex A90-54	3	10.23	25.0	17.4
5957	Decumbent top ex A90-54	100	13.45	17.2	19.8
6141	High % dry matter ex 5957	12	16.19	18.3	20.7
6144	Low % dry matter ex 5957	4	10.57	19.6	19.5

PRELIMINARY VARIETY AND STRAIN TESTING

An experiment with the following sixteen sugar beet varieties and strains was planted on April 26, 1962.

Variety and strain description

CS7	Standard tonnage variety
6133	High sucrose percentage ex CS7
6136	High root weight ex CS7
6139	High percentage dry matter of the petiole ex CS7
6142	Low percentage dry matter of the petiole ex CS7
6145	Visual root ex CS7
A90-54	High sucrose percentage variety
6134	High sucrose percentage ex A90-54
6137	High root weight ex A90-54
6140	High percentage dry matter of the petiole ex A90-54
5957	Decumbent tops ex A90-54
6135	High sucrose percentage ex 5957
6138	High root weight ex 5957
6141	High percentage dry matter of the petiole ex 5957
6144	Low percentage dry matter of the petiole ex 5957
6147	Visual root ex 5957

A randomized block design with eight replications was used. One row plots 60 feet long were planted. The emerged seedling stands were thinned in the usual manner. On June 22, one healthy leaf with its petiole and on September 5 one petiole was taken from each of twenty plants from each plot. The dry matter content was determined as described above. On September 25, 1962 the roots from 25 feet of row from each plot were harvested and processed for analysis.

On September 28, 1962 seed of the above 16 varieties and strains was planted in 6 inch diameter pots, using a 3:1:1 soil, peat moss and sand mixture as the growing medium. The experiment was replicated eight times and placed into a cabinet growth chamber of the Department of Genetics, University of Alberta, Edmonton. Illumination of approximately 1400 foot candles was provided with both fluorescent and incandescent light bulbs for sixteen hour photoperiods which were

alternated with eight hour dark periods. The humidifier was turned on for the first two weeks (between 75 and 80 per cent during the photoperiod and approximately 100 per cent during the dark period), turned off the third week (between 65 and 75 per cent during the photoperiod and between 95 and 100 per cent during the dark period) and set to dehumidify on the fourth week (between 40 and 50 per cent during the photoperiod and between 65 and 75 per cent during the dark period). The temperature was maintained constantly at 21°C. After emergence the seedlings were thinned to 25 plants per pot. Twenty-eight days later (October 26) the leaves and petioles were harvested and the percentage dry matter determined. The data were analyzed statistically.

RESULTS

GROWTH STUDY

Observations made in the growth study were root weight, percentage sucrose, percentage purity and percentage dry matter of the roots. In addition sucrose yield, root dry matter yield, and percentage sucrose on dry weight basis were calculated. These data were obtained on the two varieties on each of eight harvest dates in 1961 and 1962.

Fresh root weight

Fresh root yield data for CS7 and A90 are given in Table II and are depicted graphically in Fig. 2 for both 1961 and 1962. The results obtained in the two years are in close agreement. In both years CS7 yielded significantly more than A90 on each date, with the difference becoming progressively greater as the growing season advanced. In both years A90 was characterized by a rapid decline in growth rate after the end of August, whereas CS7 showed a more gradual decline in growth rate. However, both varieties continued to increase in weight until the last harvest date, although the unit increments between successive dates were not always statistically significant on the last few harvest dates.

Sucrose yield

The data for sucrose yield are given in Table III and depicted in Fig. 3. The yield of sucrose per acre increased on a straight line basis during that part of the growing season studied in both 1961 and 1962. In both years CS7 made statistically significant unit increases as measured on each harvest date. However, for A90, there were several intervals during which unit increments were not statistically significant. These intervals were between harvest dates VII and VIII (Table III) in 1961 and dates IV and V in 1962. CS7 yielded significantly more sucrose

TABLE II

ROOT YIELD IN TONS PER ACRE

harvest date	Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961						
I	3.68	2.94	0.14	0.41	0.58	12.87
II	9.63	6.83	0.34	1.04	1.44	12.75
III	14.79	10.22	0.45	1.36	1.90	11.04
IV	18.32	13.52	0.28	0.85	1.19	5.45
V	21.30	14.70	0.38	1.15	1.60	6.50
VI	23.26	15.18	0.70	2.12	2.95	11.30
VII	24.53	16.22	0.61	1.86	2.59	9.31
VIII	25.31	16.75	0.50	1.50	2.09	7.32
S.E.M.	0.54	0.31				
L.S.D. .05	1.54	0.89				
L.S.D. .01	2.06	1.19				
C.V.%	8.68	7.37				
1962						
I	6.51	5.31	0.16	0.53	0.79	7.61
II	10.90	8.27	0.27	0.90	1.32	7.90
III	15.15	10.66	0.38	1.27	1.87	8.28
IV	18.68	12.98	0.23	0.76	1.12	4.05
V	20.91	13.13	0.27	0.91	1.35	4.54
VI	22.96	15.12	0.46	1.53	2.26	6.79
VII	24.80	15.36	0.60	2.02	2.98	8.48
VIII	25.13	16.63	0.31	1.04	1.54	4.20
S.E.M.	0.36	0.33				
L.S.D. .05	1.03	0.95				
L.S.D. .01	1.37	1.27				
C.V.%	5.64	7.77				

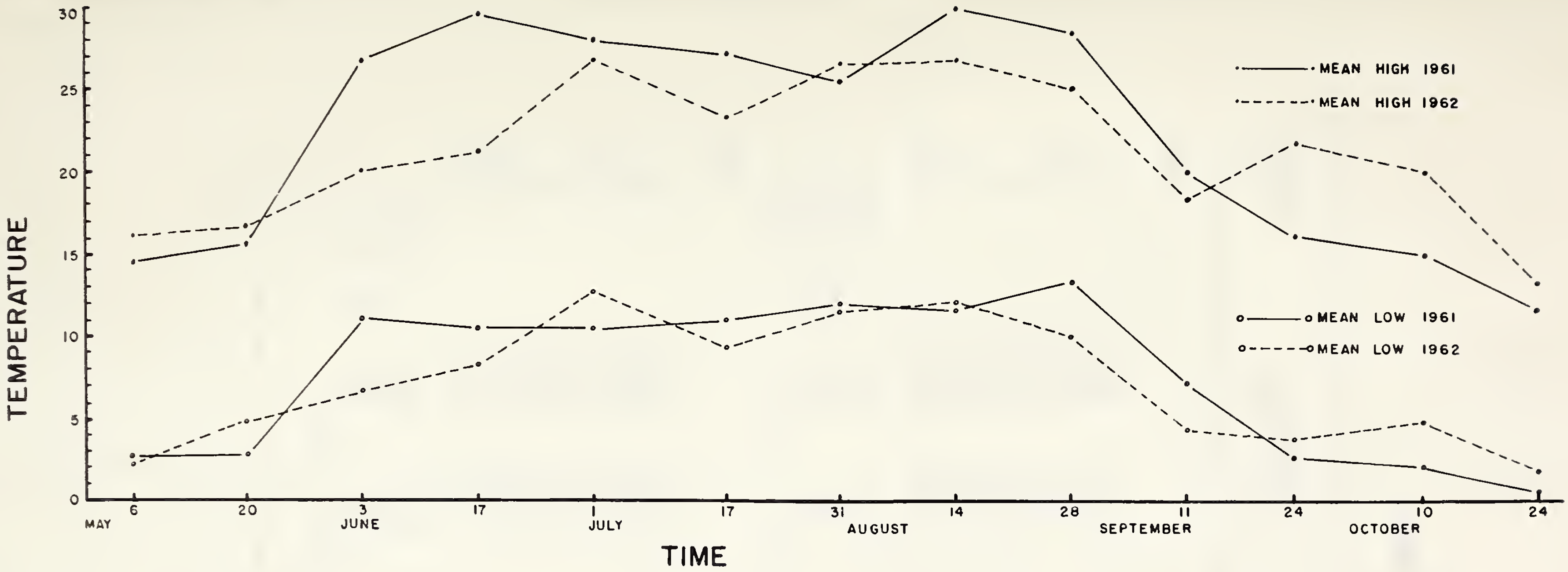

FIGURE 1. BIWEEKLY MEAN AIR TEMPERATURE (°C) DURING THE GROWING SEASONS OF 1961 AND 1962.

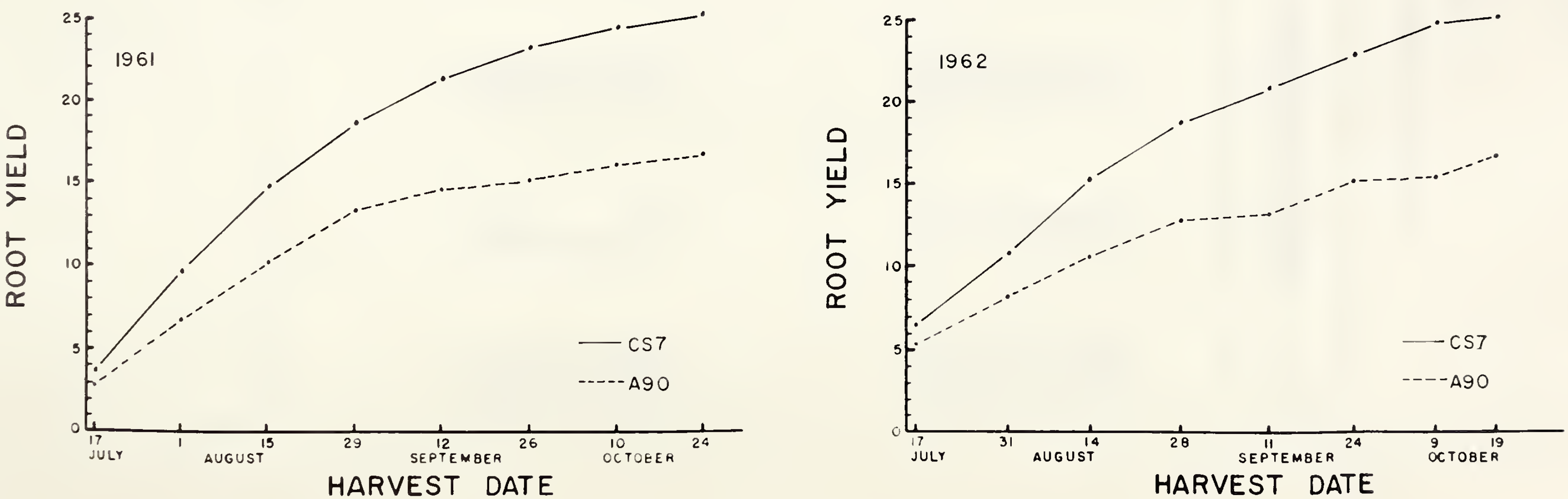

FIGURE 2. ROOT YIELD IN TONS PER ACRE OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

TABLE III

SUCROSE YIELD IN POUNDS PER ACRE

Harvest date	Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961						
I	556	473	22	67	N.S.	12.96
II	1773	1357	84	255	355	16.16
III	3036	2337	86	259	361	9.49
IV	4361	3696	82	247	345	6.09
V	5195	4025	108	326	454	6.98
VI	6373	4830	196	592	825	10.55
VII	7387	5694	176	532	741	8.08
VIII	7858	5976	146	442	616	6.41
S.E.M.	125	113				
L.S.D. .05	355	322				
L.S.D. .01	473	430				
C.V.%	7.74	9.04				
1962						
I	1255	1142	34	N.S.	N.S.	8.34
II	2517	2182	79	265	N.S.	9.62
III	4312	3413	101	338	500	7.41
IV	5484	4335	65	218	322	3.73
V	6697	4677	89	298	440	4.43
VI	7930	5756	149	499	737	6.15
VII	9114	6274	208	697	1029	7.66
VIII	9467	6872	138	462	683	4.76
S.E.M.	114	126				
L.S.D. .05	327	358				
L.S.D. .01	436	477				
C.V.%	5.58	7.55				

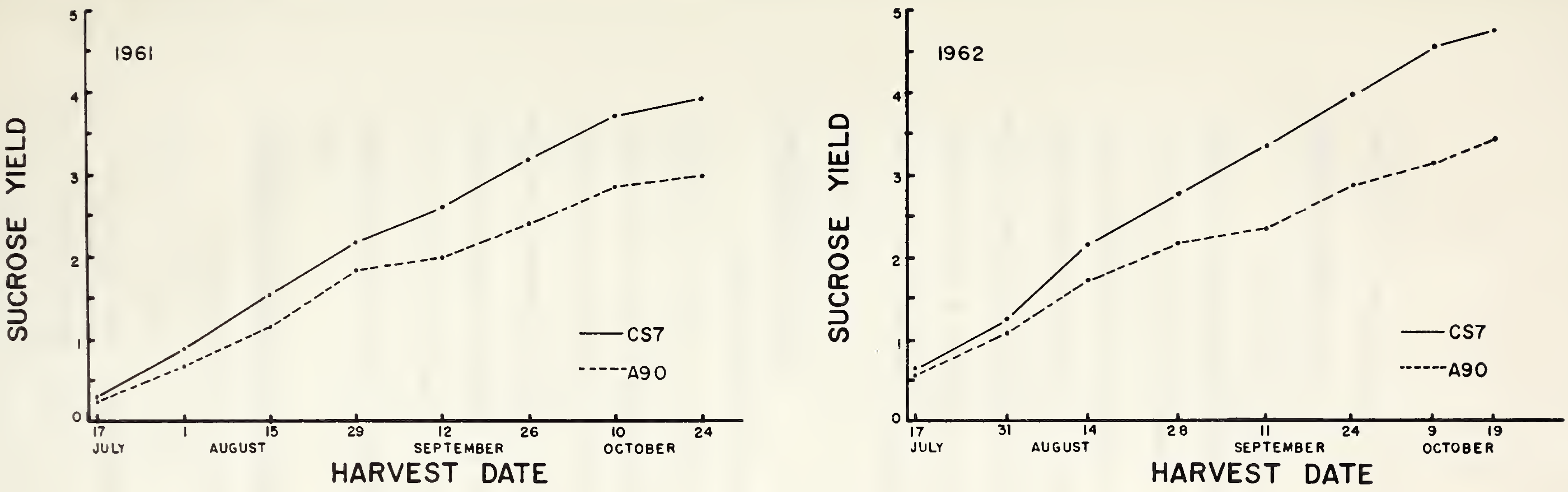

FIGURE 3. THE SUCROSE YIELD IN TONS PER ACRE OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

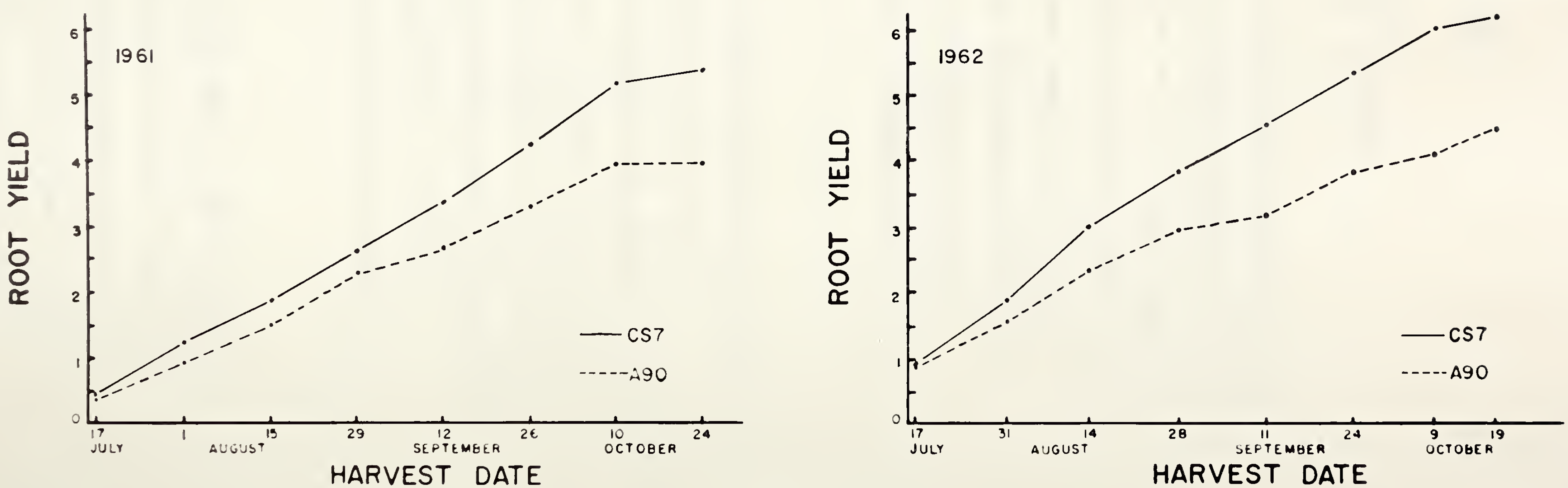

FIGURE 4. THE ROOT DRY MATTER YIELD IN TONS PER ACRE OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

than A90 on every harvest date except date I in 1962.

Root dry matter yield

CS7 yielded significantly more root-dry-matter than A90 on all dates in both years except date I in 1962 as shown in Table IV and Fig. 4. In both years the difference between the two varieties became progressively greater as the growing season advanced. In both years CS7 showed significant increments in yield on each date except date VIII. A90 made significant growth increments on every date except date VIII in 1961 and date V in 1962. In both years the cumulative increase in yield of root-dry-matter appeared to follow a straight line for both varieties.

Percentage sucrose

The percentage sucrose data for both varieties and both years are given in Table V and depicted graphically in Fig. 5. A90 was consistently higher in percentage sucrose than CS7, although this difference was not significant on the first harvest date in 1961. The percentage sucrose increments between successive harvest dates for CS7 and A90 were not significant for dates V and VIII in 1961 and for A90 on harvest date VIII in 1962. All other increments were significant. In 1962 the percentage sucrose was consistently above that for 1961 on each harvest date.

Percentage sucrose on dry weight basis

This character varied very much from 1961 to 1962 as shown in Table VI and Fig. 6. In spite of the apparently correlated variation of CS7 and A90 in 1961 they differed significantly on dates III, VI, and VIII with CS7 being higher on date III and A90 being higher on dates VI and VIII. Both CS7 and A90 reached a peak on date IV and dropped

TABLE IV

ROOT DRY MATTER YIELD IN TONS PER ACRE

Harvest date		Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961							
I		0.43	0.36	0.02	0.06	N.S.	14.03
II		1.22	0.95	0.06	0.21	N.S.	15.13
III		1.88	1.55	0.07	0.23	N.S.	11.51
IV		2.63	2.30	0.07	0.23	0.33	7.74
V		3.36	2.69	0.07	0.25	0.37	6.93
VI		4.26	3.30	0.14	0.48	0.70	10.25
VII		5.18	3.93	0.15	0.52	0.77	9.63
VIII		5.35	3.97	0.10	0.33	0.49	5.67
S.E.M.		0.09	0.08				
L.S.D.	.05	0.25	0.23				
L.S.D.	.01	0.33	0.30				
C.V. %		8.10	9.36				
1962							
I		0.98	0.89	0.03	N.S.	N.S.	9.38
II		1.89	1.60	0.06	0.20	N.S.	9.80
III		3.02	2.36	0.07	0.25	0.37	7.99
IV		3.83	2.97	0.04	0.13	0.19	3.18
V		4.54	3.17	0.06	0.20	0.29	4.36
VI		5.32	3.84	0.12	0.39	0.58	7.27
VII		6.01	4.09	0.15	0.49	0.73	8.26
VIII		6.18	4.49	0.08	0.27	0.39	4.22
S.E.M.		0.08	0.08				
L.S.D.	.05	0.23	0.24				
L.S.D.	.01	0.31	0.32				
C.V. %		5.87	8.12				

TABLE V

PERCENTAGE SUCROSE

Harvest date		Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C. V. %
1961							
I		7.64	8.15	0.21	N.S.	N.S.	7.23
II		9.15	9.95	0.17	0.52	0.73	5.10
III		10.31	11.41	0.14	0.43	0.59	3.55
IV		11.91	13.66	0.14	0.44	0.61	3.06
V		12.24	13.70	0.16	0.49	0.68	3.35
VI		13.76	15.91	0.13	0.40	0.56	2.46
VII		15.10	17.56	0.18	0.55	0.77	3.10
VIII		15.59	17.84	0.12	0.38	0.52	2.05
S.E.M.		0.28	0.25				
L.S.D.	.05	0.78	0.70				
L.S.D.	.01	1.05	0.94				
C.V.%		6.52	5.16				
1962							
I		9.65	10.75	0.06	0.18	0.27	1.53
II		11.55	13.17	0.11	0.35	0.52	2.41
III		14.25	16.00	0.10	0.34	0.51	1.92
IV		14.70	16.70	0.16	0.52	0.77	2.81
V		16.02	17.82	0.06	0.18	0.27	0.92
VI		17.27	19.03	0.12	0.42	0.62	1.94
VII		18.38	20.43	0.14	0.45	0.67	1.97
VIII		18.83	20.66	0.14	0.47	0.70	2.02
S.E.M.		0.15	0.14				
L.S.D.	.05	0.42	0.41				
L.S.D.	.01	0.56	0.54				
C.V. %		2.77	2.40				

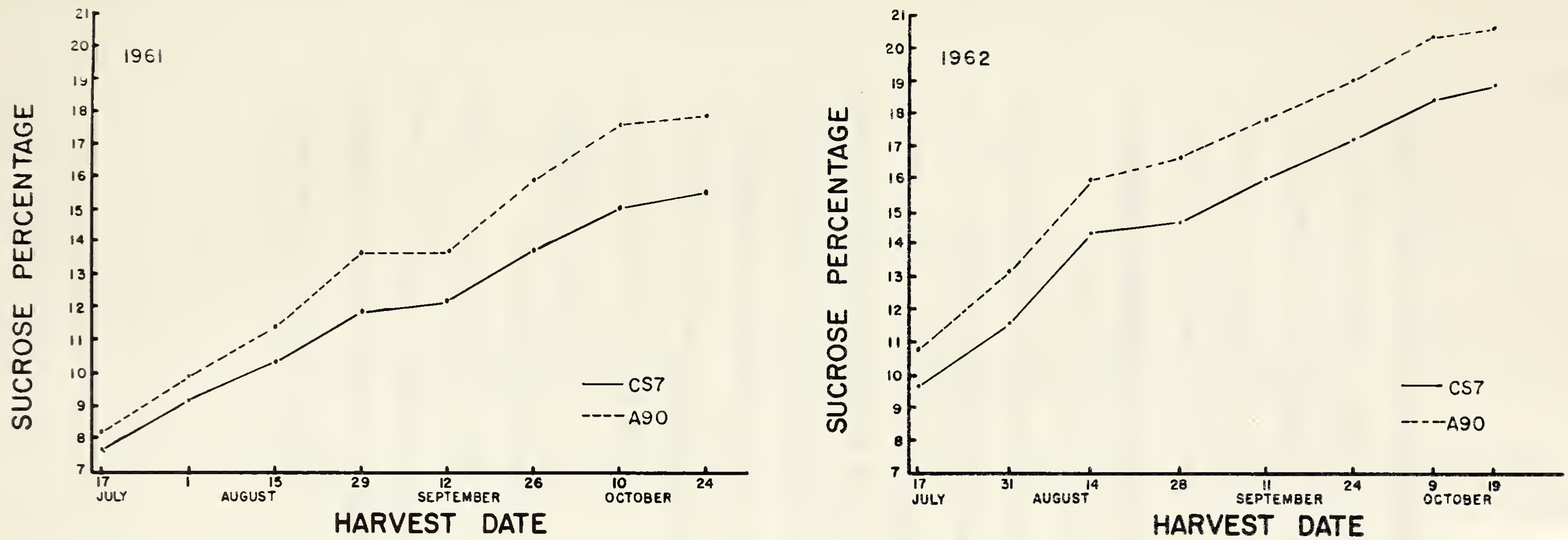

FIGURE 5. THE SUCROSE PERCENTAGE ON FRESH WEIGHT OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

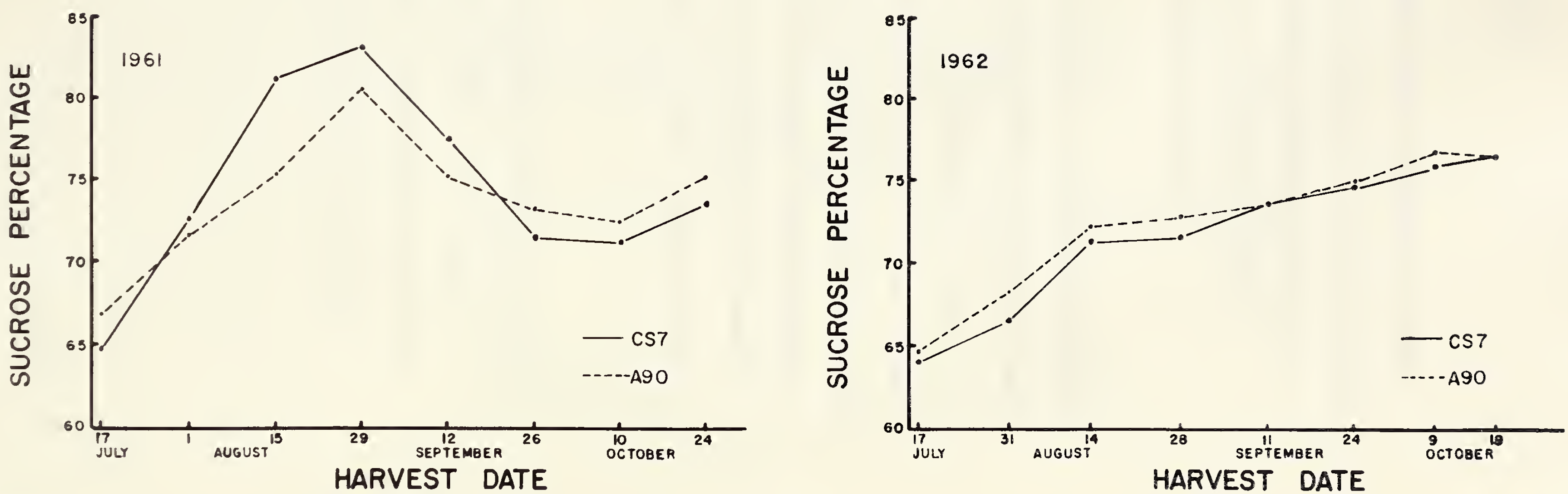

FIGURE 6. THE SUCROSE PERCENTAGE ON DRY WEIGHT OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

significantly until date VI after which there was no significant change. In 1962 there was a steady increase for both varieties. The unit increases of percentage sucrose on a dry weight basis were significant except for dates IV, VI, and VIII for CS7 and dates IV, V and VIII for A90. On dates II, III and IV A90 was significantly higher than CS7.

Percentage dry matter of the roots

In 1961 as well as in 1962 both varieties increased in percentage dry matter of the root as the growing season advanced (Table VII and Fig. 7). However, the unit increments were not significant for each harvest date. In 1961 CS7 made significant unit increments on all harvest dates except I,II,VII and VIII, while A90 made significant unit increments on all dates except date VIII. On this date A90 showed a slight decline. In 1962 both varieties made significant unit increments for all except date VIII. A90 was significantly higher than CS7 on all dates in both years except date I in 1962.

Percentage purity

CS7 and A90 did not differ significantly in percentage purity except on dates VIII in 1962, as shown in Table VIII. Fig. 8 shows that in 1961 both varieties increased rapidly in percentage purity and attained a peak on date III and did not vary significantly from this on subsequent harvest dates.

TABLE VI

PERCENTAGE SUCROSE ON DRY WEIGHT BASIS

Harvest date		Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961							
I		64.8	66.9	1.97	N.S.	N.S.	8.40
II		72.7	71.7	1.38	N.S.	N.S.	5.40
III		81.2	75.3	1.23	3.7	5.2	4.48
IV		83.1	80.6	0.97	N.S.	N.S.	3.38
V		77.4	75.1	1.27	N.S.	N.S.	4.72
VI		71.5	73.3	0.41	1.25	1.75	1.62
VII		71.3	72.5	0.39	N.S.	N.S.	1.53
VIII		73.6	75.2	0.39	1.17	N.S.	1.47
S.E.M.		1.30	1.36				
L.S.D.	.05	3.70	3.85				
L.S.D.	.01	4.93	5.14				
C.V. %		4.95	5.20				
1962							
I		64.0	64.6	0.56	N.S.	N.S.	2.45
II		66.6	68.3	0.38	1.26	N.S.	1.58
III		71.4	72.3	0.25	0.86	N.S.	0.92
IV		71.6	72.9	0.32	1.06	N.S.	1.24
V		73.7	73.7	0.22	N.S.	N.S.	0.83
VI		74.6	75.0	0.54	N.S.	N.S.	2.03
VII		75.9	76.8	0.50	N.S.	N.S.	1.85
VIII		76.4	76.5	0.30	N.S.	N.S.	1.09
S.E.M.		0.36	0.37				
L.S.D.	.05	1.01	1.04				
L.S.D.	.01	1.35	1.39				
C.V. %		1.41	1.43				

TABLE VII

PERCENTAGE DRY MATTER OF THE ROOTS

Harvest date		Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961							
I		11.78	12.16	0.30	N.S.	N.S.	6.77
II		12.60	13.90	0.18	0.55	0.77	3.79
III		12.73	15.18	0.21	0.62	0.87	4.00
IV		14.37	16.96	0.27	0.81	1.13	4.61
V		15.86	18.30	0.26	0.82	1.14	4.31
VI		19.23	21.70	0.14	0.46	0.71	1.98
VII		21.16	24.21	0.30	1.01	1.50	3.77
VIII		21.18	23.71	0.13	0.44	0.65	1.65
S.E.M.		0.34	0.32				
L.S.D.	.05	0.96	0.91				
L.S.D.	.01	1.27	1.21				
C.V. %		5.91	4.94				
1962							
I		15.08	16.65	0.19	0.63	0.94	3.37
II		17.36	19.28	0.14	0.46	0.68	2.11
III		19.95	22.13	0.18	0.60	0.88	2.39
IV		20.54	22.90	0.16	0.53	0.78	2.03
V		21.74	24.18	0.10	0.35	0.51	1.28
VI		23.17	25.37	0.09	0.29	0.43	1.01
VII		24.24	26.61	0.14	0.47	0.69	1.55
VIII		24.60	27.00	0.16	0.53	0.79	1.75
S.E.M.		0.17	0.24				
L.S.D.	.05	0.49	0.68				
L.S.D.	.01	0.65	0.91				
C.V. %		2.34	2.94				

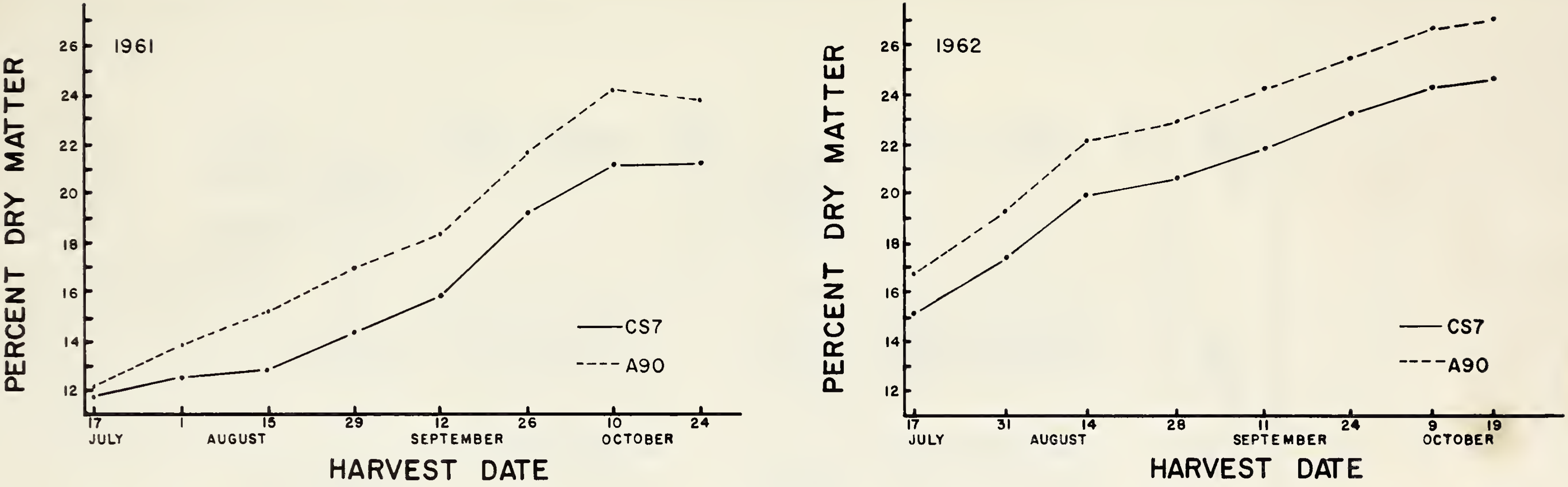

FIGURE 7. THE PERCENT DRY MATTER OF THE ROOTS OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

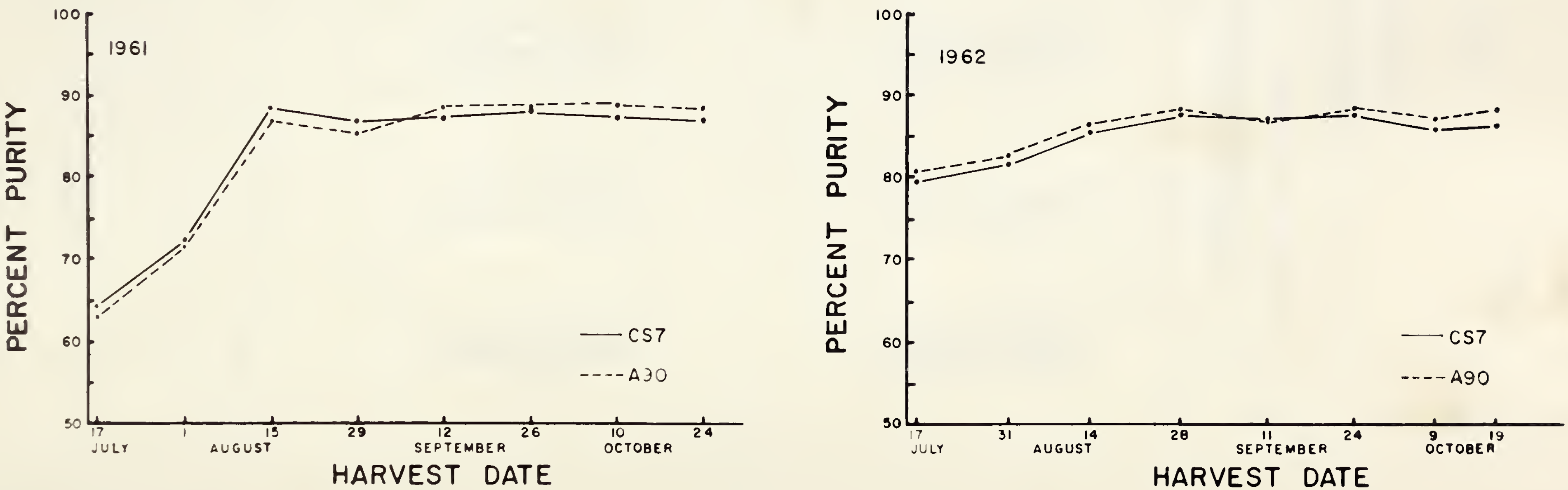

FIGURE 8. THE PERCENT PURITY OF CS7 AND A90 ON EACH OF EIGHT HARVEST DATES IN 1961 AND 1962.

TABLE VIII

PERCENTAGE PURITY

Harvest date		Variety CS7	Variety A90	S.E.M.	Significant difference .05	Significant difference .01	C.V. %
1961							
I		64.3	63.2	1.27	N.S.	N.S.	5.52
II		72.5	71.7	1.25	N.S.	N.S.	4.87
III		88.5	87.0	0.81	N.S.	N.S.	2.62
IV		86.9	85.3	0.64	N.S.	N.S.	2.10
V		87.1	88.5	0.99	N.S.	N.S.	3.15
VI		88.0	88.3	0.82	N.S.	N.S.	2.62
VII		87.2	88.8	1.04	N.S.	N.S.	3.33
VIII		86.9	88.3	0.49	N.S.	N.S.	1.60
S.E.M.		1.44	0.98				
L.S.D.	.05	4.10	2.79				
L.S.D.	.01	5.46	3.71				
C.V. %		4.93	3.36				
1962							
I		79.5	80.5	0.39	N.S.	N.S.	1.37
II		81.7	82.7	0.64	N.S.	N.S.	1.83
III		85.3	86.3	0.57	N.S.	N.S.	1.89
IV		87.5	88.1	0.62	N.S.	N.S.	1.98
V		87.0	86.6	0.64	N.S.	N.S.	2.07
VI		87.5	88.1	0.62	N.S.	N.S.	1.98
VII		85.8	87.1	0.48	N.S.	N.S.	1.58
VIII		86.1	88.1	0.23	0.77	1.13	0.74
S.E.M.		0.64	0.50				
L.S.D.	.05	1.82	1.42				
L.S.D.	.01	2.43	1.90				
C.V. %		2.14	1.65				

VARIETY BY FERTILIZER

The data for fresh root yield, percentage sucrose, sucrose yield, percentage purity, percentage dry matter of the roots, dry root yield and percentage sucrose on dry matter basis are given in Table IX.

Fresh root yield

CS7 significantly exceeded A90 in root yield in both the normal and high fertilizer treatments. The high fertilizer treatment resulted in yield increases for both varieties but was significant only for CS7.

Percentage sucrose

A90 was significantly higher than CS7 at both fertilizer levels. The high fertilizer treatment resulted in highly significant reductions in percentage sucrose for both varieties.

Sucrose yield

CS7 produced significantly more sucrose than A90. Neither variety responded with increased sucrose yield to the high level of fertilizer. An increase in sucrose yield due to higher root yields was offset by the reduction in percentage sucrose.

P ercentage purity

A90 had a higher percentage purity than CS7 on both the normal and high fertilizer plots. The high fertilizer treatments had a significantly lower percentage purity.

Percentage dry matter of the roots

A90 had significantly higher dry matter percentage than CS7 on both fertilizer treatments. However, the high fertilizer treatment significantly reduced the dry matter content of both varieties.

TABLE IX

EFFECT OF FERTILIZER ON THE PERFORMANCE OF TWO VARIETIES

Treatment				Roots, fresh, tons per acre	Roots, fresh, % sucrose	Sucrose, pounds per acre	Purity, %	Roots, % dry matter	Roots, dry, tons per acre	Roots, dry, % sucrose
H.F.*	CS7			26.61	17.4	9236	83.7	23.25	6.18	74.7
	A90			16.46	19.6	6446	85.6	25.66	4.22	76.4
		S.E.M.		0.83	0.21	301	0.56	0.17	0.21	0.58
		L.S.D.	.05	2.46	0.62	894	1.67	0.51	0.61	N.S.
		L.S.D.	.01	3.37	0.85	1226	N.S.	0.70	0.84	N.S.
N.F.**	CS7			24.07	19.2	9247	85.5	25.32	6.09	75.9
	A90			15.64	21.2	6618	87.3	27.71	4.33	76.4
		S.E.M.		0.83	0.21	301	0.56	0.17	0.21	0.58
		L.S.D.	.05	2.46	0.62	894	1.67	0.51	0.61	N.S.
		L.S.D.	.01	3.37	0.85	1226	N.S.	0.70	0.84	N.S.
CS7	H.F.			26.61	17.4	9236	83.7	23.25	6.18	74.7
	N.F.			24.07	19.2	9247	85.5	25.32	6.09	75.9
		S.E.M.		0.69	0.15	252	0.56	0.20	0.16	0.58
		L.S.D.	.05	2.07	0.46	N.S.	1.70	0.59	N.S.	N.S.
		L.S.D.	.01	N.S.	0.65	N.S.	N.S.	0.82	N.S.	N.S.
A90	H.F.			16.46	19.6	6446	85.6	25.66	4.22	76.4
	N.F.			15.64	21.2	6618	87.3	27.71	4.33	76.4
		S.E.M.		0.69	0.15	252	0.56	0.20	0.16	0.58
		L.S.D.	.05	N.S.	0.46	N.S.	1.70	0.59	N.S.	N.S.
		L.S.D.	.01	N.S.	0.65	N.S.	N.S.	0.82	N.S.	N.S.
	CS7			25.34	18.3	9241	84.6	24.28	6.14	75.3
	A90			16.05	20.4	6532	86.5	26.69	4.28	76.4
		S.E.M.		0.59	0.08	213	0.40	0.12	0.14	0.41
		L.S.D.	.05	1.74	0.23	632	1.18	0.36	0.43	N.S.
		L.S.D.	.01	2.38	0.32	867	1.62	0.49	0.58	N.S.
	H.F.			21.54	18.48	7842	84.7	24.45	5.20	75.5
	N.F.			19.85	20.2	7933	86.4	26.52	5.21	76.1
		S.E.M.		0.36	0.04	135	0.40	0.15	0.07	0.41
		L.S.D.	.05	1.14	0.13	N.S.	1.26	0.49	N.S.	N.S.
		L.S.D.	.01	1.64	0.18	N.S.	N.S.	0.70	N.S.	N.S.

* High fertilizer treatment
** Normal fertilizer treatment

<u>Root dry matter yield</u>

CS7 yielded significantly more than A90 but no significant differences were observed between normal and high fertilizer treatments.

<u>Percentage sucrose on dry matter basis</u>

No significant differences between varieties or fertilizer treatments were observed.

<u>INDIVIDUAL PLANT SELECTION</u>

The data for sucrose yield, root yield, percentage sucrose and percentage dry matter of the petiole, with their respective standard errors, significant differences and coefficients of variability, are presented in Table X.

The three progenies, 6139, 6140 and 6141, from plants selected for high percentage dry matter of the petiole had a significantly higher percentage dry matter of the petiole than their respective parents, CS7, A90-54 and 5957. Of the selections for low percentage dry matter of the petiole, 6142 had a significantly lower percentage dry matter of the petiole than its parent, CS7; whereas, 6144 was not significantly lower than its parent, 5957.

Of the three, high-percentage dry matter selections, 6139 had a significantly higher percentage sucrose than its parent, whereas the increase in percentage sucrose of 6140 and 6141 over their respective parents approached statistical significance. The low-percentage dry matter selection 6142 was significantly lower than CS7 in percentage sucrose, while 6144 was not significantly lower than 5957.

The selections for high percentage dry matter resulted in significant reductions in root weight for 6139 and 6141 but not for

TABLE X

PERFORMANCE OF THE PROGENIES OF PLANT SELECTIONS FOR PERCENTAGE DRY MATTER OF THE PETIOLE

Accession number	Description	Petiole, % dry matter	Roots, % sucrose	Roots, tons per acre	Sucrose, pounds per acre	Purity, %
CS7	Standard tonnage	11.74	17.98	20.05	7202	87.0
6139	High % dry matter sel. from CS7	12.65	18.64	18.07	6710	87.9
6142	Low % dry matter sel. from CS7	10.92	17.59	19.85	6981	85.5
A90-54	High-sucrose-content Udycz A	13.35	19.81	15.52	6144	88.5
6140	High % dry matter sel. from A90-54	14.24	20.14	12.55	5054	88.5
6143	Low % dry matter sel. from A90-54	-	-	-	-	-
5957	Decumbent top sel. from A90-54	13.56	20.05	12.60	5056	87.5
6141	High % dry matter sel. from 5957	14.98	20.38	12.16	4956	88.7
6144	Low % dry matter sel. from 5957	12.81	19.85	14.58	5788	87.4
Standard error of the mean		0.14	0.13	0.55	189	0.68
Least significant difference P.05		0.39	0.37	1.53	529	1.9
Least significant difference P.01		0.51	0.49	2.02	700	2.5
Coefficient of variability (%)		3.04	1.95	9.44	8.64	2.19

6140, whereas the selections for low percentage dry matter resulted in progenies with a significant increase in root weight for 6144 but not for 6142.

None of the progenies had purities significantly different from their parents.

PRELIMINARY VARIETY AND STRAIN TESTING

The data for sucrose yield, root yield, percentage sucrose and percentage dry matter are given in Table XI. Significant differences were obtained for each of the characters studied. Table XII gives the correlation coefficients for sucrose yield, root yield, percentage sucrose, and percentage dry matter of the roots versus percentage dry matter of the leaves and petioles for each of the three dates tested. All correlation coefficients were highly significant. Fig. 9 shows the regression of root yield and percentage sucrose on percentage dry matter of the leaves and petioles.

TABLE XI

MEAN PERCENTAGE DRY MATTER, YIELD AND PERCENTAGE SUCROSE OF THREE VARIETIES AND THIRTEEN STRAINS

Accession number	Percentage dry matter after given days of growth 28*	57*	132**	152***	Sucrose, pounds per acre	Roots, tons per acre	Roots, % sucrose
CS7	7.38	10.29	11.74	24.04	7202	20.05	17.98
6133	7.21	10.77	11.75	24.43	7308	19.99	18.29
6136	6.95	10.26	11.48	23.39	7351	20.92	17.56
6139	7.20	10.68	12.65	25.07	6710	18.07	18.64
6142	6.60	9.81	10.92	23.19	6981	19.85	17.59
6145	7.33	10.11	11.98	24.08	7566	21.04	17.99
A90-54	7.92	10.66	13.35	26.35	6144	15.52	19.81
6134	7.62	10.59	13.94	27.03	5476	13.35	20.51
6137	7.47	10.47	12.59	25.36	6655	17.51	19.01
6140	7.79	10.88	14.24	26.80	5054	12.55	20.14
5957	8.20	10.86	13.56	26.61	5056	12.60	20.05
6135	7.47	11.03	14.05	26.95	5205	12.94	20.24
6138	8.03	10.82	12.77	25.64	6466	16.92	19.13
6141	8.09	11.13	14.98	27.13	4956	12.16	20.38
6144	7.31	10.96	12.81	26.32	5788	14.58	19.85
6147	7.97	10.94	13.28	26.04	5335	13.57	19.65
S.E.M.	0.22	0.11	0.14	0.16	189	0.55	0.13
L.S.D. .05	0.61	0.32	0.39	0.46	529	1.53	0.37
L.S.D. .01	0.81	0.42	0.51	0.60	700	2.02	0.49
C.V. %	8.21	3.04	3.04	1.81	8.64	9.44	1.95

TABLE XII

SIMPLE CORRELATION COEFFICIENTS BASED ON THE MEANS OF THREE VARIETIES AND THIRTEEN STRAINS

Variate	Sucrose, pounds per acre	Roots, fresh, tons per acre	Roots, % sucrose	Roots, % dry matter
Dry matter % after 28 days of growth*	-0.690	-0.723	+0.743	+0.768
Dry matter % after 52 days of growth*	-0.759	-0.789	+0.805	+0.836
Dry matter % after 132 days of growth**	-0.903	-0.925	+0.943	+0.954
Sucrose % after 152 days of growth***		-0.966		

* leaves and petioles

** petioles

*** roots

r value required for significance at P .01 = 0.623.

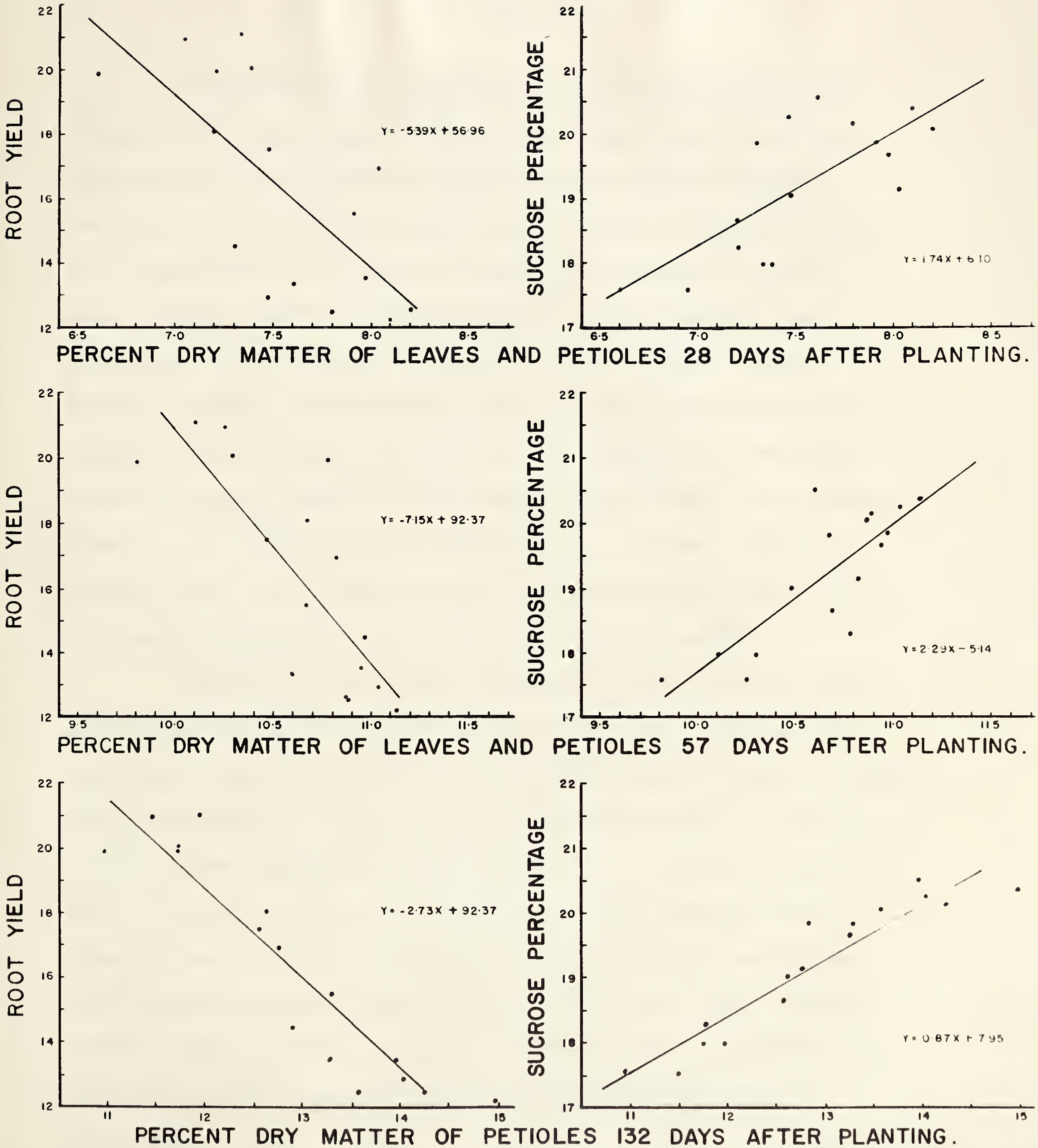

FIGURE 9. REGRESSION OF ROOT YIELD IN TONS PER ACRE AND SUCROSE PERCENTAGE 152 DAYS AFTER PLANTING ON PERCENT DRY MATTER OF LEAVES AND PETIOLES OF 3 PARENTS AND 13 SELECTED STRAINS.

DISCUSSION

The difference in root yield between a low-root-yield high-sucrose-content and a high-root-yield low-sucrose-content variety was apparent early in the growing season and was accentuated as growth continued. This observation agreed with the report by Hills et al. (25) but disagreed with the findings of Bush (12) who observed a significant variety by date-of-harvest interaction. The observation that percentage sucrose increased continuously with no plateau formation during the growing period sampled agreed with some results (25) but disagreed with the report of Ulrich (53). He described the process of percentage sucrose increase in the roots as going through three distinct phases: 1. an increase to 8 to 10 per cent, 2. a plateau at which it remained stable for an extended period during root growth followed by, 3. a period of rapid increase at the onset of cooler weather.

The rate of fresh weight accumulation declined fairly rapidly after the end of August (Fig. 2) with the growth rate of A90 declining more rapidly than that of CS7. It is noteworthy that the decline in growth rate corresponded to a rapid drop in air temperature (Fig. 1). This is a well known phenomenon of plant growth. Fig. 4, however, does not reveal any decline in the rate of root dry weight accumulation until after October 10 for CS7. Similarly, the rate of sucrose accumulation for CS7 did not decrease with the onset of cold weather. A90, however, showed a slight decline in the rate of root dry matter and sucrose accumulation after the end of August, corresponding to the lower temperature.

Of special interest is the increase in percentage sucrose (Fig.7). A rapid increase in percentage sucrose has been ascribed to the advent of

low temperatures late in the growing season. However, the advent of cool temperatures did not stimulate an increased rate of percentage sucrose increase. Furthermore, if the high percentage sucrose were due primarily to cool temperatures late in the season, then the percentage sucrose in 1961 should have exceeded that of 1962, since the temperatures in late September and throughout October were lower in 1961 than in 1962. However, the percentage sucrose was higher in 1962 than in 1961. The results of this investigation did not lend support to Ulrich's findings (55) that the preharvest date is of greatest importance in determining the percentage sucrose in the roots. Others, (60, 61) suggest that nyctotemperature is more important than day temperature. It was difficult to assess this in these experiments as in 1961 both day and night temperatures during late September and throughout October were below those of 1962. However, it may be noted that during July and most of August the night temperatures for both years were very similar and yet the percentage sucrose in 1962 was consistently higher than in 1961. This difference could not be attributed to a difference in night temperature. The day temperatures during June and July of 1962 had been consistently below those for 1961. It must either be suggested that day temperature is important in producing high percentage sucrose or that some other factor was responsible for the higher percentage sucrose in 1962.

It has been reported that respiration rates at 10°C are less than 25 per cent the rate at 25°C (5) and that the metabolic uptake of minerals has a high temperature coefficient (26). Photosynthesis (44) on the other hand also decreases with lowered temperature although the primary photochemical reaction (3, 44) and sucrose translocation (31)

are not very sensitive to lowered temperature. The increase observed in percentage dry matter of the root (Fig. 7) corroborates the report that plants reduce their water uptake more rapidly than transpiration as the temperature drops (36). Therefore, the increase in percentage sucrose which is normally observed under cooler climates could be at least partially explained by the interaction of these factors. The respiration rate would be much reduced, with a lesser decline in photosynthesis resulting in a constant production of net photosynthate. Since translocation is not reduced (31) the sucrose would be stored in the root. The decline in respiration rate would reduce the rate of sucrose utilization for new cell growth and the reduced water uptake with a lesser reduction in transpiration would aid to increase the sucrose concentration in the root.

In 1961 the percentage sucrose on dry weight (Fig. 6) reached very high levels during August, a period of very rapid fresh-root-weight increase (Fig. 2), then dropped in September. In 1962 this pattern was not observed. The difference in day temperature between 1961 and 1962 may have been responsible for this result.

The writer attributes the major difference observed between 1961 and 1962, for sucrose percentage on dry weight, to differences in climatic conditions prevailing during the two years. The observation that the average percentage sucrose from approximately 40,000 acres of commercial beets was 15.44 in 1961 and 17.16 in 1962 supports this view.

The difference in root yield and percentage sucrose of a variety of sugar beets grown in different years is large and similar in magnitude to the difference observed between genetically divergent varieties in

any one year. Likewise environmentally induced character correlations are similar in sign and intensity to genetically determined character correlations. This observation suggests that the variations in response within any one variety obtained experimentally as observed by agronomists, physiologists and biochemists could be simulated by divergent selections for the genetically controlled processes. Furthermore, this observation strongly suggests that the biochemical basis of the observed divergence in phenotype due to environmental changes, is the same or similar to the biochemical basis of the observed divergence in phenotypes due to genetic differences.

The preceding paragraphs have discussed predominantly the environmental effects, whereas the subsequent discussion will consider phenomena established in other organisms and relate this knowledge to the observations attributable to genetic differences between the sugar beet varieties and strains studied.

CS7 is higher and increases more rapidly in dry root yield and sucrose yield than A90. On the first harvest date the differences were relatively small (Fig. 3 and 4) but on date VIII these differences were about 20 times as great. On date I A90 yielded 89 per cent of CS7 while on date VIII it yielded only 73 per cent of CS7. This suggests that the basic difference became more clearly expressed as the season advanced. Since it is logical to assume that the two varieties remained genetically unchanged throughout the growing period it could be suggested that the more pronounced differences in dry matter yield at the later growth stage is a result of enzyme changes which took place within the plant prior to this time. It is logical to conclude that CS7 had a more

efficient or a more readily adaptable metabolic system than A90. Of importance, however, would be the identification of the specific system or systems responsible for the different rates of growth observed for CS7 and A90.

The lower sucrose concentration in CS7 suggests that the sucrose or its precursor was respired more rapidly for the production of new cells, water and nutrient uptake, translocation and metabolism. The higher sucrose content of A90 suggests that the assumed lower respiration rate could not be due to inadequate substrate. It might therefore, be supposed that from very early stages of growth CS7 was more efficient in respiration than A90. During subsequent growth A90 and CS7 differ progressively more. The decline in the growth rate was greater in A90 than CS7. This could be attributed to the continuing higher concentration of sucrose in A90 acting as an excess-substrate inhibitor (52) which would still further reduce growth by reducing the respiration rate. The high sucrose concentration in the root could ultimately suppress the rate of translocation and thus reduce net photosynthesis by endproduct inhibition. This phenomenon has not yet been demonstrated to be active in higher plants, but has been adequately demonstrated for the microorganism Escherishia coli (57).

The observation that A90 falters in rate of dry matter accumulation with the onset of cooler weather in early September, suggests that its respiration system may be more temperature sensitive than that of CS7, or that its genetically-controlled adaptive ability (15) is inferior to that CS7. These phenomena have been observed in a wide range of organisms. Mutants possessing temperature-sensitive (38) and temperature-independent (18) enzymes have been described for the microorganisms,

Neurospora crassa and Escherichia coli (28). Strains of mice have been shown to differ in their adaptability and tolerance to heat (22). Genetically-controlled heat-sensitivity has been described for Drosophila melanogaster (24) and gene mutations for respiratory deficiencies are known in yeast (49).

The addition of high fertilizer levels resulted in a greater fresh weight increase for CS7 than for A90. It is suggested that the added fertilizer may have induced a higher respiration rate in CS7 than in A90. The phenomenon of enzyme induction has been clearly demonstrated in Escherisha coli (34) and Neurospora crassa (29). The biochemical aspects of induced respiration have also been studied on several higher plants. It has been shown that the washing of carrot slices (1,2), application of 2, 4-dichlorophenooxyacetic acid on corn, oat and pea seedlings (32,33) and dye to maize roots (13) and nitrates to barley roots (62), induced higher rates of respiration. In each case mentioned, the increase in respiration rate was due mainly to an increase in the pentose phosphate sequence. It is assumed that the growth response due to addition of a high level of fertilizer to sugar beets was a result of nitrate induced respiration. It has been shown that triphosphopyridine nucleotide is present preferentially in its reduced form in all cells and tissues studied (27). This has been attributed to the fact that the sum of processes utilizing reduced triphosphopyridine nucleotide is less active than the two TPNH- supplying dehydrogenating steps of the oxidative pentose phosphate pathway. Thus it becomes comprehensible that the operation of the pentose phosphate cycle, which requires the presence of the oxidized TPN, is controlled by all the processes

oxidizing TPNH. It is suggested that provision of excess nitrate fertilizer to the sugar beets provided this oxidant, which would oxidize the TPNH and thus remove the rate limiting step in the pentose phosphate cycle of respiration. The induced increase in rate of respiration resulted in a significant net increase in fresh-root-weight for CS7. However, the sucrose content of the root was decreased by supplying hexoses to the pentose phosphate sequence to provide reducing power for the nitrates and carbon skeletons for the incorporation of the nitrogen into the amino acids. This is supported by recent work (17) which showed that high levels of nitrogen fertilizer increased the level of amino acids in the sugar beet root. Nevertheless, the fact that there was no reduction in total sucrose produced (Table IX) indicates that in spite of the high hexose utilization for nitrate reduction (41, 59) and amino acid synthesis, photosynthesis (3, 35) was stimulated sufficiently to compensate for this carbon diversion.

The reduction in percentage sucrose of A90 (Table IX) suggests that its respiration rate responded in a similar way to the addition of nitrate fertilizer. However, the lack of a significant increment in fresh weight indicates that additional growth did not take place. This suggests that the enzyme action required to increase cell size or division did not become induced. This observation that A90 did not respond through increased root weight to high levels of nitrate fertilizer agrees with a similar experiment by Hills et al. (25). The reduced sucrose content in A90 suggests that the pentose phosphate cycle may have been stimulated, but the absence of a significant fresh weight increase suggests that some other system was rate limiting.

Previously it was suggested that some enzymes in A90 may be more temperature-sensitive than those in CS7.

However, in spite of the probable increased respiration rates, with corresponding increases in fresh root weight for CS7, there was no net increase in root dry matter produced. This, however, might reflect the necessity for a longer period of photosynthesis at a reduced respiration rate to utilize the extra photosynthetic capacity of the newly produced leaves to increase the percentage sucrose of the larger storage roots. Probably the nitrate levels were still high at harvest and thus did not permit a cessation of new growth to allow for greater increases in sucrose storage. Figure 10 presents a schematic illustration of processes possibly differentiating CS7 and A90.

These experiments have given results which suggest that the respiration system functions at a faster rate in a high-root-yield, low-sucrose-content variety than in a low-root-yield, high-sucrose-content variety. However, the possibility that these two varieties differ in the endogenous production of respiratory inhibitors or stimulators (45) is not excluded. Moreover, the phenomenon of endproduct inhibition has been demonstrated in microorganisms (57, 58) and although its operation has been suggested in sugar beets (52) it requires verification. If endproduct inhibition is active, then the lower sucrose concentration might also permit a more rapid rate of sucrose storage, since the storage concentration gradient would be lower. The resulting less-inhibited translocation could result in a more-rapid photosynthetic rate with a greater total sucrose production per plant. Therefore, it would be desirable to have a plant which would keep its sucrose concentration

PHOTOSYNTHESIS

SUCROSE TRANSLOCATION - not reduced by low temperature

SUCROSE STORAGE - high sucrose concentration may reduce respiration by substrate inhibition and reduce photosynthesis by endproduct inhibition

RESPIRATION - A90 probably has a genetically controlled lower respiration rate than CS7, thus utilizing less sucrose and contributing to a higher sucrose concentration

- A90 is probably more sensitive to lower temperatures and thus uses less sucrose than CS7

- CS7 probably responds more to available NO_3 (oxidant) and thus uses more sucrose in respiration and grows faster than A90

ENERGY

NEW CELL CONSTITUENTS

NUTRIENT UPTAKE

GROWTH

Fig. 10 Schematic illustration of processes possibly differentiating a high-root-weight low-sucrose-content variety (CS7) and a low-root-weight high-sucrose-content variety (A90).

low by achieving maximum storage-root growth.

The importance of demonstrating the presence or absence of endproduct inhibition in sucrose storage and differences between varieties in rate of enzyme adaptation and rates of root respiration and whether these differences, if they do exist,do, in fact, influence total sucrose production per plant , is realized when one recognizes the constant search by plant breeders for a sugar beet variety embodying high-root-weight and high-sucrose-concnetration. If the systems discussed above are actually operating phenomena in sugar beets, then plant breeders and processors may need to revise their objectives and methods in order to achieve maximum sucrose production per unit area. The design of these experiments did not provide sufficient information to establish with certainty the operation of these phenomena nor for identifying the specific enzyme systems differentiating these two varieties. However, the results presented do provide sufficient evidence to justify more-specific biochemical-genetical studies in the future, of enzyme systems in the sugar beet.

Plants selected for high percentage dry matter of the petiole, consistently produced progeny high in percentage dry matter of the petiole, and plants selected for low percentage dry matter of the petiole produced progeny low in percentage dry matter of the petiole (Table X). Likewise progenies of plants selected for high percentage dry matter of the petiole were significantly higher in percentage sucrose than were progenies of plants selected for low percentage dry matter of the petiole. These results confirm the positive correlations obtained between percentage dry matter of the petiole and percentage sucrose (7) and substantiates that percentage dry matter and percentage sucrose are under the control

of the same or related biochemical mechanism. On a biochemical basis this may be visualized as a dynamic enzymatically administered equilibrium between sucrose and pulp. This view is supported by data presented by Barbour and Wang (4) which showed that 24 per cent of the labelled sucrose injected into a "mature" sugar beet root was incorporated in the insoluble pulp fraction within 24 hours. This is supported also by the results from the variety by fertilizer experiment. Whereas high fertilizer reduced the percentage sucrose of the roots significantly, it also reduced the percentage dry matter significantly, resulting in a non-significant change in percentage sucrose on dry weight. The possibility and the practical value of selecting individual plants for high percentage sucrose and high root weight by using the character, percentage dry matter of the petiole, has been demonstrated by this experiment.

Although the practical implications of an effective method for the evaluation of numerous strains in plant breeding programs for yield and percentage sucrose are evident and will not be discussed further as such, the preliminary testing experiment allows an extension of the growth phenomenon discussed above. Twenty eight days after planting, with temperatures continuously at 21°C, the varieties and strains had already differentiated sufficiently in percentage dry matter to demonstrate a meaningful negative correlation ($r = -0.723$) with potential root yield and a positive correlation ($r = +0.743$) with potential percentage sucrose as measured in a field experiment (Table XII). The correlations values were higher with the observations made 57 days after planting ($r = -0.789$ and $+ 0.805$ respectively) and increased still further with observations made 132 days after planting ($r = -0.925$ and $+ 0.943$ respectively)

and the values became consistently more closely orientated along the regression line (Table XI and Fig. 9) as each subsequent observation date approached the actual root harvest date.

The data discussed here corroborates the views presented above. Assuming the respiration rate is low in a strain and the photosynthetic rate is normal, only a little of the sucrose produced would be utilized in respiration and consequently the active uptake of water would be low, (6, 36) thus resulting in a high percentage dry matter. The strain equally efficient photosynthetically but with a higher respiration rate would utilize more of the sucrose to produce new cells and absorb water. These two reactions would reduce the solids concentration, first by utilizing sucrose in respiration, and secondly by using respiratory energy to absorb additional water. This would produce plants low in percentage dry matter. This phenomena as well as some others could be illustrated by comparing strains 6141 and 6142 (Table XI). On June 22, 6141 was 1.32 per cent units higher in dry matter than 6142. This difference could be ascribed primarily to differences in sucrose utilization in respiration and water absorption. On September 5 however, the difference was 4.06 per cent units. This difference in percentage dry matter would still reflect the basic respiratory difference, with accentuation due to additional substrate inhibition of respiration resulting in the high percentage dry matter and percentage sucrose. the fact that the correlation values increased as the length of the growing period increased, substantiates this and also suggests, as indicated above, that the sensitivity of some strains to lowered temperature could be greater than that of others.

Further experiments with modified environments may achieve a higher correlation value between percentage dry matter of the petiole and potential root yield and percentage sucrose after a very short period of growth. With modified controlled conditions it may be possible to select, for breeding purposes, plants or strains possessing systems which would respond in the desired manner to anticipated variable environmental conditions. More decisively analytical experiments are required to relate positively the system or systems responsible for the above behaviour with the characterization of the individual enzyme differences or other factors responsible for the observed results.

SUMMARY AND CONCLUSIONS

The results of sugar beet growth and selection experiments are presented in this dissertation. Presented evidence shows that high-root-yield, low-sucrose-content and low-root-yield, high-sucrose-content varieties differentiate at an early age of growth and increase in root weight and percentage sucrose in a generally steady rate during the last three months of growth during their vegetative development. A greater decline in growth rate was observed for the low-root-yield high-sucrose-content variety at the onset of cool weather in early September. Data, is discussed, which suggests that varieties and strains differ in enzyme adaptability, substrate inhibition, endproduct inhibition and respiration rates.

The results obtained establish that percentage dry matter of the petiole is under genetic control and that effective selection can be made for this character with simultaneous significant changes in root weight and percentage sucrose. Data is presented which indicates that the potential root yield and percentage sucrose of sugar beet varieties and strains, under field conditions, may be predicted by indexing seedlings, produced in a growth chamber, for percentage dry matter of the leaves and petioles. The results suggest that percentage dry matter may be a more sensitive measure of endogenous metabolic capacity than are such conventional measurements as root weight and percentage sucrose.

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